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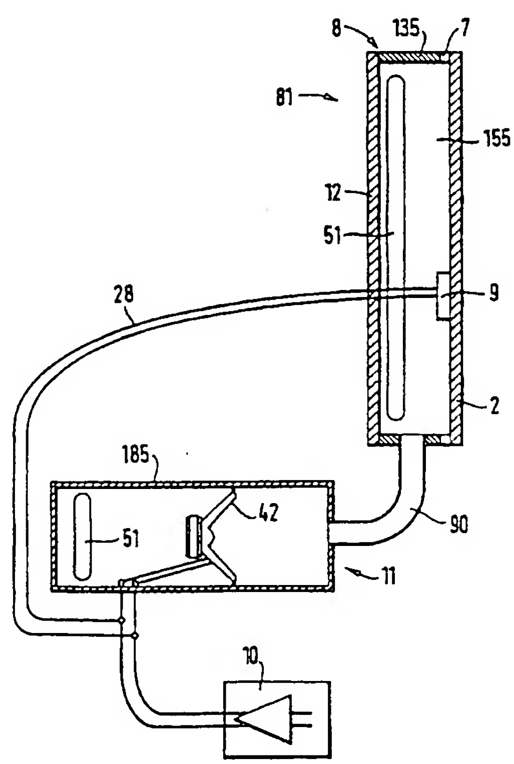
(57) Abstract

A loudspeaker (81) comprising an enclosure, an acoustic radiator (2) in the enclosure, a compliant suspension (3) mounting the radiator in the enclosure for pistonic movement relative thereto, and transducer means (9) for driving the radiator pistonically, characterized in that the radiator is a panel-form distributed mode acoustic radiator, by a first transducer mounted wholly and exclusively on the radiator to vibrate the radiator to cause it to resonate, and by means (11) for varying the air pressure in the enclosure to cause the radiator to move pistonically.



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LOUDSPEAKERS WITH PANEL-FORM ACOUSTIC RADIATING ELEMENTS

DESCRIPTION

TECHNICAL FIELD

The invention relates to loudspeakers and more particularly to loudspeakers comprising panel-form acoustic radiating elements.

BACKGROUND ART

It is known from GB-A-2262861 to suggest a panel-form loudspeaker comprising:-

a resonant multi-mode radiator element being a unitary sandwich panel formed of two skins of material with a spacing core of transverse cellular construction, wherein the panel is such as to have ratio of bending stiffness (B), in all orientations, to the cube power of panel mass per unit surface area (μ) of at least 10;

a mounting means which supports the panel or attaches

to it a supporting body, in a free undamped manner;

and an electro-mechanical drive means coupled to the panel which serves to excite a multi-modal resonance in the radiator panel in response to an electrical input within a working frequency band for the loudspeaker.

DISCLOSURE OF INVENTION

Embodiments of the present invention use members of nature, structure and configuration achievable generally and/or specifically by implementing teachings of our co-pending PCT application no. (our case P.5711) of even date herewith. Such members thus have capability to sustain and propagate input vibrational energy by bending waves in operative area(s) extending transversely of thickness often but not necessarily to edges of the member(s); are configured with or without anisotropy of bending stiffness to have resonant mode vibration components distributed over said area(s) beneficially for acoustic coupling with ambient air; and have predetermined preferential locations or sites within said area for transducer means, particularly operationally active or moving part(s) thereof effective in relation to acoustic vibrational activity in said area(s) and signals, usually electrical, corresponding to acoustic content of such vibrational activity. Uses are envisaged in co-pending International application No. (our file P.5711) of even date herewith for such members as or in "passive" acoustic devices without transducer means, such as for reverberation or for acoustic filtering or for acoustically "voicing" a space or room; and as or in

"active" acoustic devices with transducer means, such as in a remarkably wide range of sources of sound or loudspeakers when supplied with input signals to be converted to said sound, or in such as microphones when exposed to sound to be converted into other signals.

This invention is particularly concerned with active acoustic devices in the form of loudspeakers.

Members as above are herein called distributed mode acoustic radiators and are intended to be characterised as in the above PCT application and/or otherwise as specifically provided herein.

The invention provides a loudspeaker comprising an enclosure, an acoustic radiator in the enclosure, a compliant suspension mounting the radiator in the enclosure for limited pistonic movement relative thereto, and transducer means for driving the radiator, characterised in that the radiator is a panel-form distributed mode acoustic radiator, by a first transducer mounted wholly and exclusively on the radiator to vibrate the radiator to cause it to resonate, and by means for varying the air pressure in the enclosure to cause the radiator to move pistonically. The air pressure varying means may comprise an air pump. The air pump may comprise a subsidiary enclosure, a pistonic driver mounted in the subsidiary enclosure and means coupling the interiors of the respective enclosures such that air pressure waves produced by motion of the pistonic driver are transmitted to the said enclosure.

Acoustically absorbent means, e.g. wadding, may be provided in the said enclosure and/or in the subsidiary enclosure.

The distributed mode acoustic radiator may comprise a panel having a lightweight cellular core sandwiching a pair of high modulus lightweight skins.

BRIEF DESCRIPTION OF DRAWINGS

The invention is diagrammatically illustrated, by way of example, in the accompanying drawings, in which:-

Figure 1 is a diagram showing a distributed-mode loudspeaker as described and claimed in our co-pending International application No. (our case P.5711);

Figure 2a is a partial section on the line A-A of Figure 1;

Figure 2b is an enlarged cross-section through a distributed mode radiator of the kind shown in Figure 2a and showing two alternative constructions, and

Figure 3 is a diagram of an embodiment of distributed-mode loudspeaker according to the present invention.

BEST MODES FOR CARRYING OUT THE INVENTION

Referring to Figure 1 of the drawings, there is shown a panel-form loudspeaker (81) of the kind described and claimed in our co-pending International application No. (our case P.5711) of even date herewith comprising a rectangular frame (1) carrying a resilient suspension (3) round its inner periphery which supports a distributed mode sound radiating panel (2). A transducer (9) e.g as described in detail with reference to our co-pending

International applications Nos. (our cases P.5683/4/5) of even date herewith, is mounted wholly and exclusively on or in the panel (2) at a predetermined location defined by dimensions x and y, the position of which location is calculated as described in our co-pending International application No. (our case P.5711) of even date herewith, to launch bending waves into the panel to cause the panel to resonate to radiate an acoustic output.

The transducer (9) is driven by a signal amplifier (10), e.g. an audio amplifier, connected to the transducer by conductors (28). Amplifier loading and power requirements can be entirely normal, similar to conventional cone type speakers, sensitivity being of the order of 86 - 88dB/watt under room loaded conditions. Amplifier load impedance is largely resistive at 6 ohms, power handling 20-80 watts. Where the panel core and/or skins are of metal, they may be made to act as a heat sink for the transducer to remove heat from the motor coil of the transducer and thus improve power handling.

Figures 2a and 2b are partial typical cross-sections through the loudspeaker (81) of Figure 1. Figure 2a shows that the frame (1), surround (3) and panel (2) are connected together by respective adhesive-bonded joints (20). Suitable materials for the frame include lightweight framing, e.g. picture framing of extruded metal e.g. aluminium alloy or plastics. Suitable surround materials include resilient materials such as foam rubber and foam plastics. Suitable adhesives for the joints (20) include

epoxy, acrylic and cyano-acrylate etc. adhesives.

Figure 2b illustrates, to an enlarged scale, that the panel (2) is a rigid lightweight panel having a core (22) e.g. of a rigid plastics foam (97) e.g. cross linked polyvinylchloride or a cellular matrix (98) i.e. a honeycomb matrix of metal foil, plastics or the like, with the cells extending transversely to the plane of the panel, and enclosed by opposed skins (21) e.g. of paper, card, plastics or metal foil or sheet. Where the skins are of plastics, they may be reinforced with fibres e.g. of carbon, glass, Kevlar (RTM) or the like in a manner known per se to increase their modulus.

Envisaged skin layer materials and reinforcements thus include carbon, glass, Kevlar (RTM), Nomex (RTM) i.e. aramid etc. fibres in various lays and weaves, as well as paper, bonded paper laminates, melamine, and various synthetic plastics films of high modulus, such as Mylar (RTM), Kaptan (RTM), polycarbonate, phenolic, polyester or related plastics, and fibre reinforced plastics, etc. and metal sheet or foil. Investigation of the Vectra grade of liquid crystal polymer thermoplastics shows that they may be useful for the injection moulding of ultra thin skins or shells of smaller size, say up to around 30cm diameter. This material self forms an orientated crystal structure in the direction of injection, a preferred orientation for the good propagation of treble energy from the driving point to the panel perimeter.

Additional such moulding for this and other

thermoplastics allows for the mould tooling to carry location and registration features such as grooves or rings for the accurate location of transducer parts e.g. the motor coil, and the magnet suspension. Additional with some weaker core materials it is calculated that it would be advantageous to increase the skin thickness locally e.g. in an area or annulus up to 150% of the transducer diameter, to reinforce that area and beneficially couple vibration energy into the panel. High frequency response will be improved with the softer foam materials by this means.

Envisaged core layer materials include fabricated honeycombs or corrugations of aluminium alloy sheet or foil, or Kevlar (RTM), Nomex (RTM), plain or bonded papers, and various synthetic plastics films, as well as expanded or foamed plastics or pulp materials, even aerogel metals if of suitably low density. Some suitable core layer materials effectively exhibit usable self-skinning in their manufacture and/or otherwise have enough inherent stiffness for use without lamination between skin layers. A high performance cellular core material is known under the trade name 'Rohacell' which may be suitable as a radiator panel and which is without skins. In practical terms, the aim is for an overall lightness and stiffness suited to a particular purpose, specifically including optimising contributions from core and skin layers and transitions between them.

Several of the preferred formulations for the panel

employ metal and metal alloy skins, or alternatively a carbon fibre reinforcement. Both of these, and also designs with an alloy Aerogel or metal honeycomb core, will have substantial radio frequency screening properties which should be important in several EMC applications. Conventional panel or cone type speakers have no inherent EMC screening capability.

In addition the preferred form of piezo and electro dynamic transducers have negligible electromagnetic radiation or stray magnet fields. Conventional speakers have a large magnetic field, up to 1 metre distant unless specific compensation counter measures are taken.

Where it is important to maintain the screening in an application, electrical connection can be made to the conductive parts of an appropriate DML panel or an electrically conductive foam or similar interface may be used for the edge mounting.

The suspension (3) may damp the edges of the panel (2) to prevent excessive edge movement of the panel. Additionally or alternatively, further damping may be applied, e.g. as patches, bonded to the panel in selected positions to damp excessive movement to distribute resonance equally over the panel. The patches may be of bitumen-based material, as commonly used in conventional loudspeaker enclosures or may be of a resilient or rigid polymeric sheet material. Some materials, notably paper and card, and some cores may be self-damping. Where desired, the damping may be increased in the construction

of the panels by employing resiliently setting, rather than rigid setting adhesives.

Effective said selective damping includes specific application to the panel including its sheet material of means permanently associated therewith. Edges and corners can be particularly significant for dominant and less dispersed low frequency vibration modes of panels hereof. Edge-wise fixing of damping means can usefully lead to a panel with its said sheet material fully framed, though their corners can often be relatively free, say for desired extension to lower frequency operation. Attachment can be by adhesive or self-adhesive materials. Other forms of useful damping, particularly in terms of more subtle effects and/or mid- and higher frequencies can be by way of suitable mass or masses affixed to the sheet material at predetermined effective medial localised positions of said area.

An acoustic panel as described above is bi-directional. The sound energy from the back is not strongly phase related to that from the front. Consequently there is the benefit of overall summation of acoustic power in the room, sound energy of uniform frequency distribution, reduced reflective and standing wave effects and with the advantage of superior reproduction of the natural space and ambience in the reproduced sound recordings.

While the radiation from the acoustic panel is largely non-directional, the percentage of phase related

information increases off axis. For improved focus for the phantom stereo image, placement of the speakers, like pictures, at the usual standing person height, confers the benefit of a moderate off-axis placement for the normally seated listener optimising the stereo effect. Likewise the triangular left/right geometry with respect to the listener provides a further angular component. Good stereo is thus obtainable.

There is a further advantage for a group of listeners compared with conventional speaker reproduction. The intrinsically dispersed nature of acoustic panel sound radiation gives it a sound volume which does not obey the inverse square law for distance for an equivalent point source. Because the intensity fall-off with distance is much less than predicted by inverse square law then consequently for off-centre and poorly placed listeners the intensity field for the panel speaker promotes a superior stereo effect compared to conventional speakers. This is because the off-centre placed listener does not suffer the doubled problem due to proximity to the nearer speaker; firstly the excessive increase in loudness from the nearer speaker, and then the corresponding decrease in loudness from the further loudspeaker.

There is also the advantage of a flat, lightweight panel-form speaker, visually attractive, of good sound quality and requiring only one transducer and no crossover for a full range sound from each panel diaphragm.

Figure 3 illustrates another way of combining pistonic

and distributed mode resonant behaviour in a loudspeaker (81). In the drawing a lightweight, rigid distributed mode sound radiator panel (2) of the kind shown in Figures 1 and 2 forms a front wall of a box-like enclosure (8) having sides (135) and a rear wall (12) e.g. of medium density fibreboard, together defining a cavity (155). A panel (51) of acoustic absorption material is provided in the cavity (155). A panel (51) of acoustic absorption material is provided in the cavity to damp standing waves. The radiator panel (2) is mounted in the enclosure (8) by means of a compliant suspension (7) e.g. to emulate the roll surround of a conventional pistonic cone loudspeaker and carries a transducer (9) of the kind described with reference to our co-pending International application Nos. (our files (P5683/4/5) of even date herewith mounted wholly and exclusively on the panel (2) at a predetermined location as described in our said co-pending International application No. (our file P.5711) of even date herewith to launch bending waves into the panel.

The interior cavity (155) of the enclosure (8) is coupled to a bass pump (11), that is to say to the interior of a box-like enclosure (185) containing a pistonic bass loudspeaker drive unit (42), by means of a pipe-like conduit (90), whereby air pressure waves of acoustic frequency in the bass region are applied to the interior (155) of the enclosure to cause the panel (2) to move pistonically on its compliant suspension (7) to produce a low frequency acoustic output. In addition the panel is

caused to resonate by the transducer (9) to cause the panel to radiate an acoustic output at higher frequencies. An amplifier (1) is arranged to feed an acoustic signal to the bass pump (11) and to the transducer (9) to drive the loudspeaker.

CLAIMS

1. A loudspeaker comprising an enclosure, an acoustic radiator in the enclosure, a compliant suspension mounting the radiator in the enclosure for pistonic movement relative thereto, and transducer means for driving the radiator pistonically, characterised in that the radiator is a panel-form distributed mode acoustic radiator, by a first transducer mounted wholly and exclusively on the radiator to vibrate the radiator to cause it to resonate, and by means for varying the air pressure in the enclosure to cause the radiator to move pistonically.

2. A loudspeaker according to claim 1, characterised in the air pressure varying means comprises an air pump.

3. A loudspeaker according to claim 2, characterised in that the air pump comprises a subsidiary enclosure, a pistonic driver mounted in the subsidiary enclosure and means coupling the interiors of the respective enclosures such that air pressure waves produced by motion of the pistonic driver are transmitted to the said enclosure.

4. A loudspeaker according to claim 3, characterised by acoustically absorbent means in the said enclosure and/or in the subsidiary enclosure.

5. A loudspeaker according to any preceding claim, characterised in that the distributed mode acoustic radiator comprises a panel having a lightweight cellular core sandwiching a pair of high modulus lightweight skins.

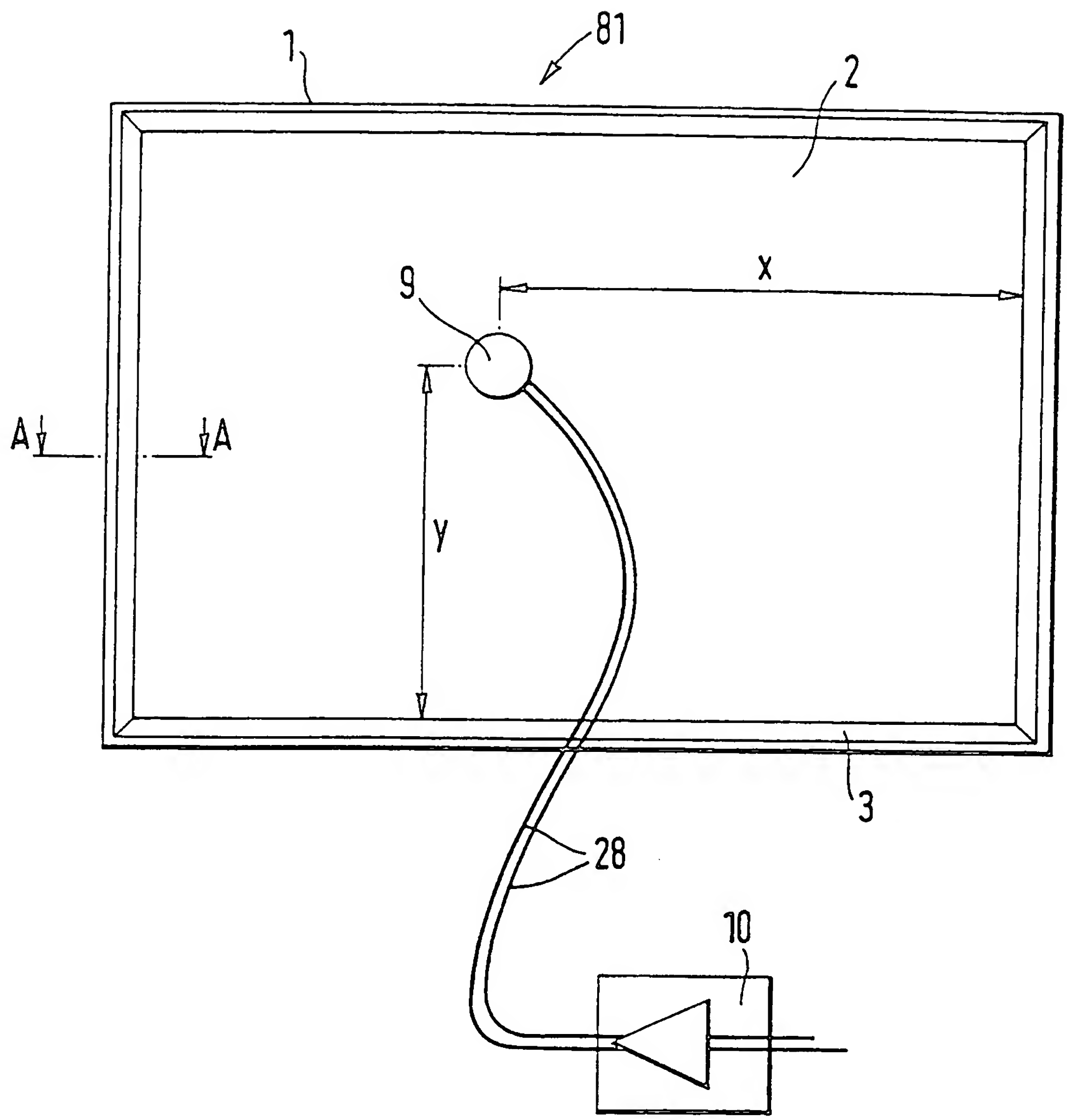

Fig. 1

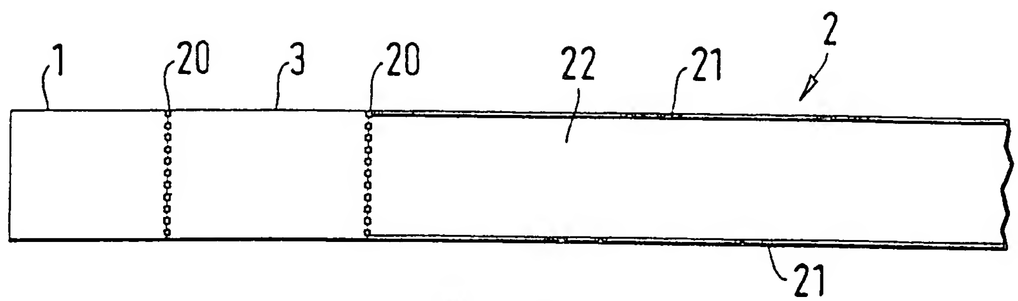

Fig. 2a

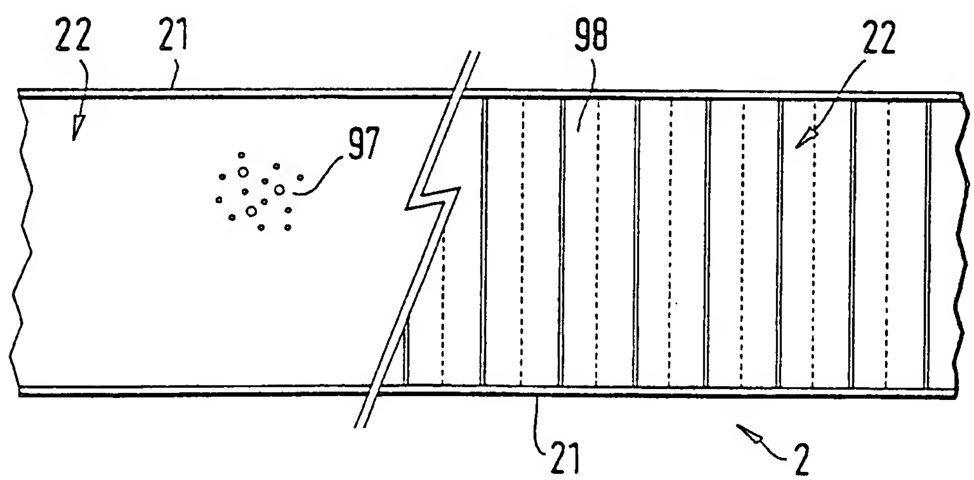

Fig. 2b

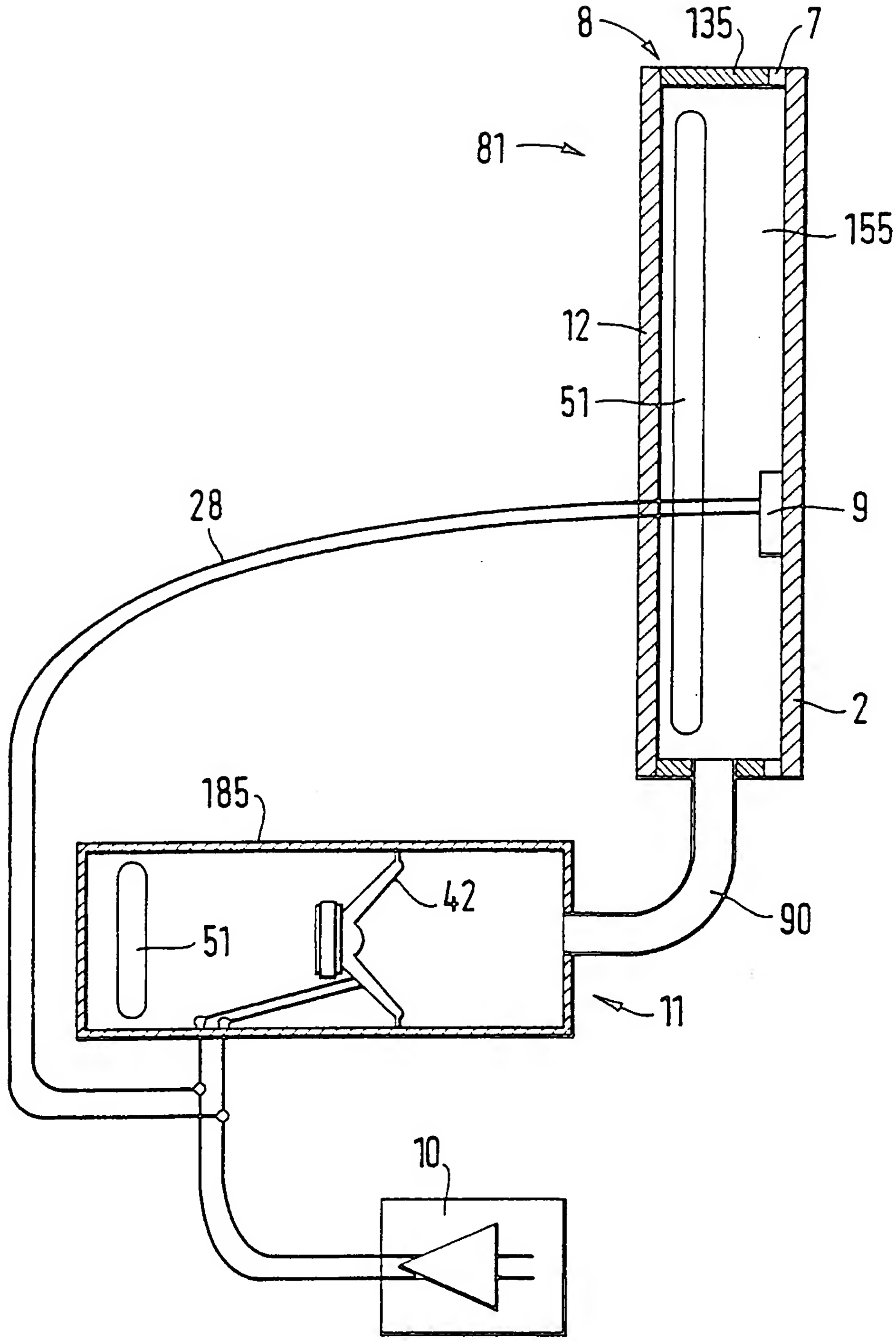

Fig.3

INTERNATIONAL SEARCH REPORT

Intern nal Application No
PCT/GB 96/02166

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04R1/02 H04R7/06 H04R1/42 H04R1/28 H04R23/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	US 3 164 221 A (RICH) 5 January 1965 see column 3, line 21 - column 4, line 53; figures ---	1 2-4
Y A	US 3 247 925 A (WARNAKA) 26 April 1966 see the whole document ---	1 5
A	EP 0 340 435 A (YAMAHA CORP) 8 November 1989 see column 8, line 24 - column 10, line 3; figure 1 ---	1
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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